



Remote sensing-based black carbon emission estimates from cropland burning in the Russian Federation

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Objectives

- 1. Estimate organic and black carbon (OCBC) emissions from cropland burning in Russia**
 - MODIS (Moderate Resolution Imaging Spectroradiometer)
 - Goal: 2003 – present
- 2. Emission estimation methodologies**
 - Bottom-up approach using burned area data (Seiler and Crutzen, 1980)
 - Fire Radiative Energy (FRE) approach
- 3. Compare results and share with collaborators**

A satellite image of a forested landscape, likely in a tropical region, showing dense green vegetation and some cleared areas. Numerous small red squares are scattered across the map, representing individual emission points or sampling locations. The text is centered over the image.

Bottom-Up Emission Estimate Approach: Preliminary Results

BC Emissions Estimates: Bottom-Up Approach

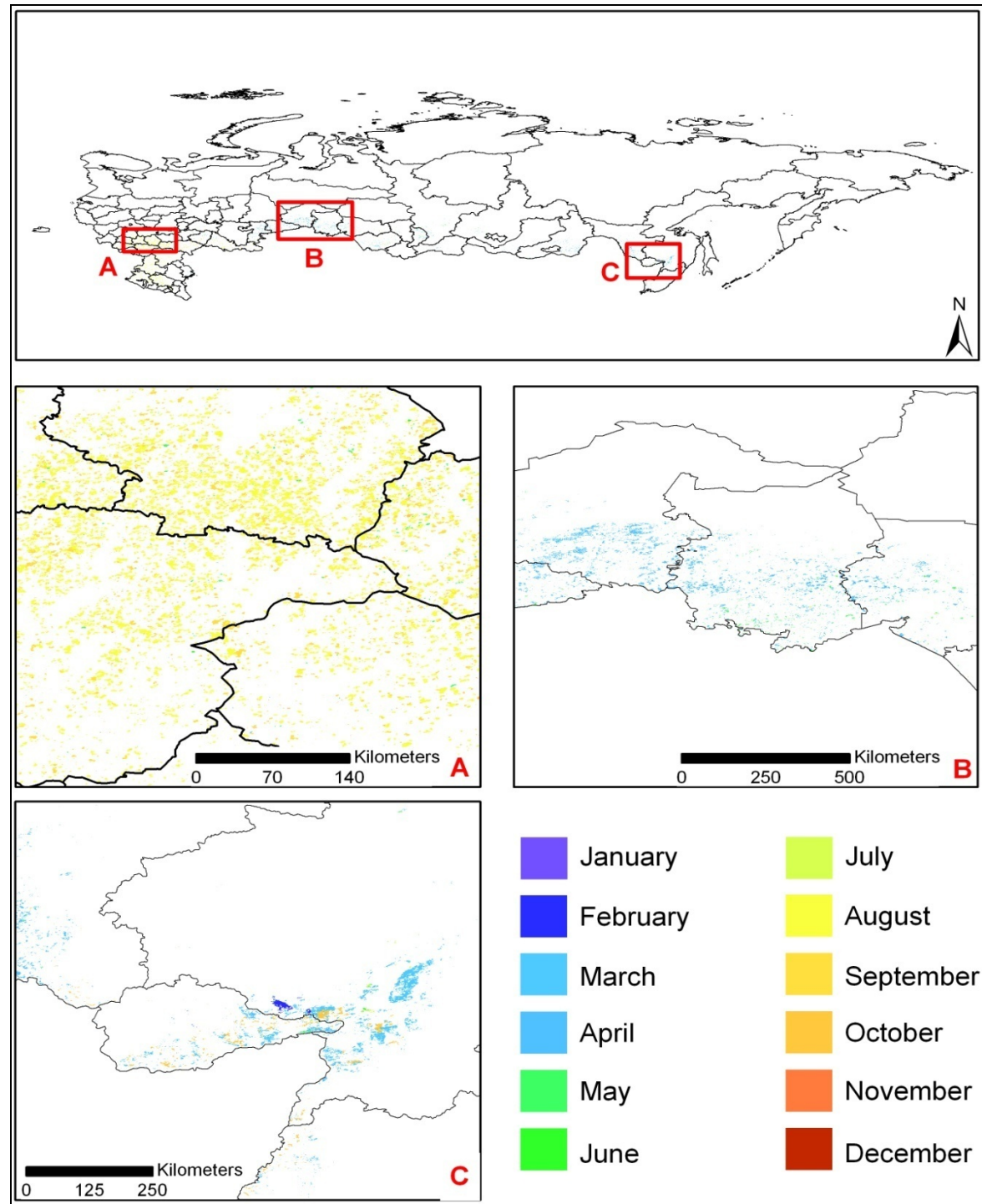
- $A * B * CE * e_i$ (Seiler and Crutzen, 1980),
where A = burned area, B = fuel load, CE = combustion efficiency, and e_i = emission factor
- Burned area derived from MCD45A1 product
 - 1 pixel of burned area $\approx 214,659 \text{ m}^2 \approx 21.5 \text{ ha}$
 - Daily detections aggregated into monthly, annual estimates of burned area

Cropland Burned Area

- Results from official MODIS Burned Area Product (Roy et al. 2002; 2005; 2008).
- MODIS Collection 5 product (MCD45A1)
 - Both Terra and Aqua detections
 - Monthly composites
 - Julian date of burned area
 - QA data not considered in this analysis
 - Ranks confidence of detection
 - Will be included in final analysis

Figure 2. Monthly Cropland Burned Area for 2008

- Cropland areas taken from 1 km MODIS Land Cover data set (Friedl et al. 2002)
- Defined as land cover values 12 and 14 from IGBP classification.



Emission Factors

Source	EF BC (g/kg)/EF OC (g/kg)
Personal communication w/ Zbigniew Klimont (IIASA; http://www.iiasa.ac.at)	0.83/2.62
Turn et al. (1997)	0.79/2.2
Andreae and Merlet (2001)	0.69/3.3
McCarty (2009)	0.46/1.52

Table 1. Emission factor sources used in bottom-up approach.

- McCarty (2009) emission factors derived from $PM_{2.5}$ emission factors for wheat residue burning in the contiguous U.S.
 - BC = 11.5% of $PM_{2.5}$ ef and OC = 38% of $PM_{2.5}$ ef

Fuel Loads and Combustion Efficiency

- Fuel load derived from wheat residue estimates for the contiguous U.S.;
 - Confirmed in field by agriculturalists.
- Combustion efficiency from scientific literature, expert knowledge, and field work.

Source	Fuel load (kg/ha)
McCarty (2009)	4300

Table 2. Fuel load value used in bottom-up approach.

Source	Combustion Efficiency
McCarty (2009)	0.85

Table 3. Combustion efficiency value used in bottom-up approach.

	2008		2009	
Month	Average BC estimate (Gg)	Average OC estimate (Gg)	Average BC estimate (Gg)	Average OC estimate (Gg)
Jan	0.0	0.0	0.0	0.0
Feb	0.2	0.7	0.0	0.0
Mar	2.3	8.1	0.1	0.4
Apr	12.5	43.5	7.4	25.8
May	2.6	9.1	6.9	24.0
Jun	0.5	1.8	0.5	1.8
Jul	1.8	6.4	3.1	10.9
Aug	13.2	46.0	3.4	11.7
Sep	3.9	13.6	2.1	7.3
Oct	2.7	9.3	1.0	3.6
Nov	0.1	0.4	0.0	0.0
Dec	0.0	0.0	0.0	0.0
Annual	39.9	138.9	24.6	85.5

Table 4. **Average** monthly BC and OC emission estimates (Gg) from all emission factor sources for 2008 and 2009.

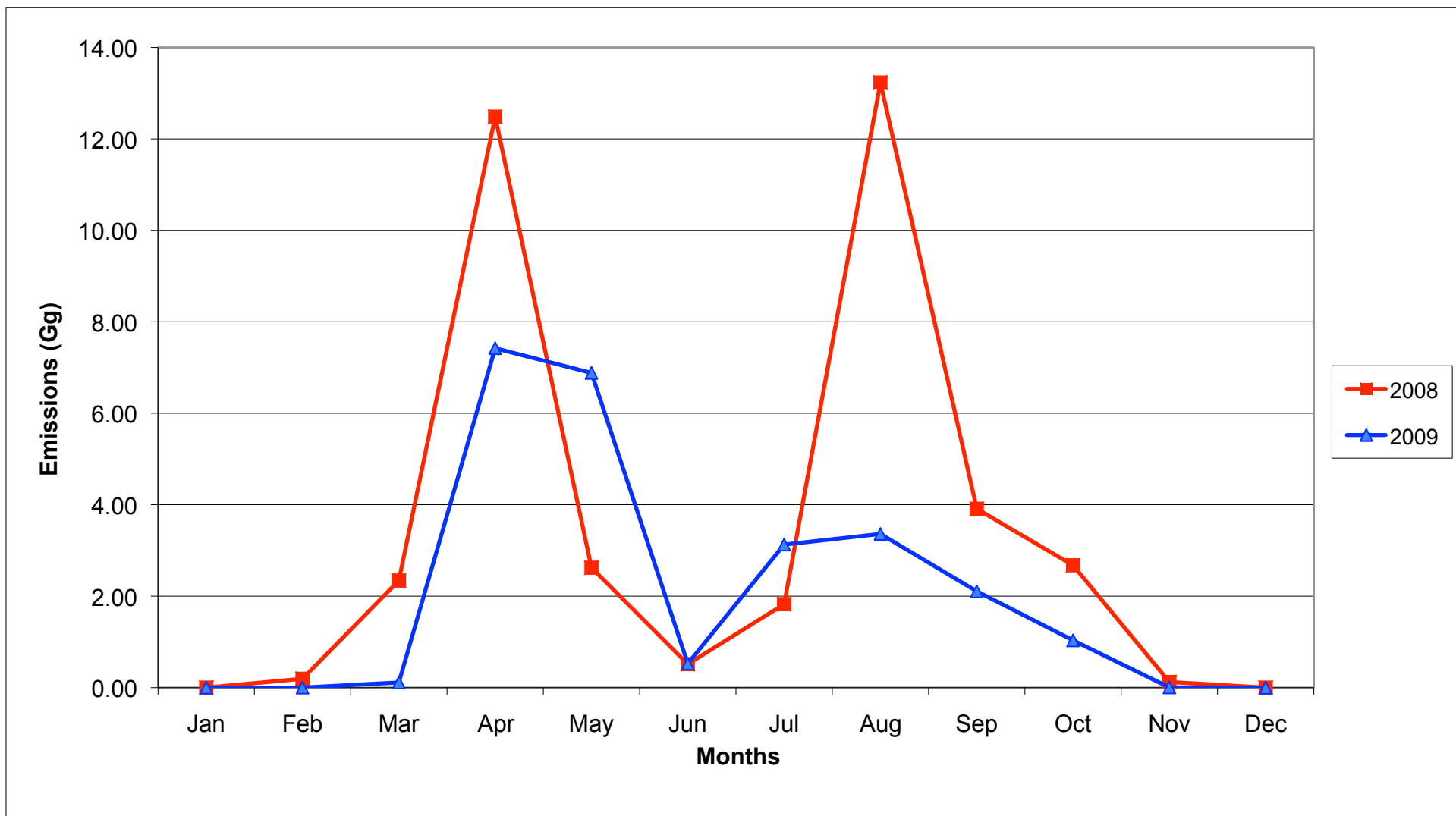


Figure 3. **Average** monthly BC emissions (Gg) from cropland burning in Russia, 2008 and 2009.

BC emission estimates from different emission factor sources

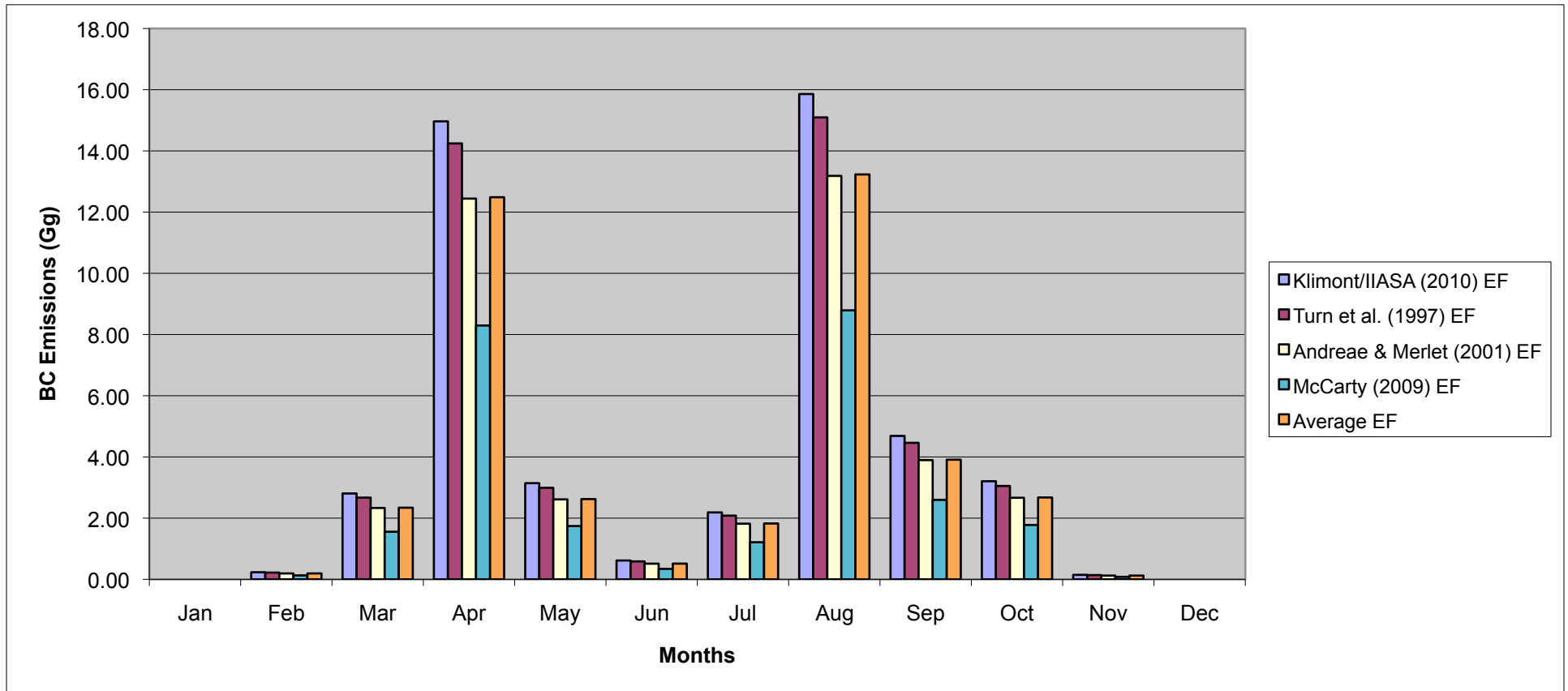
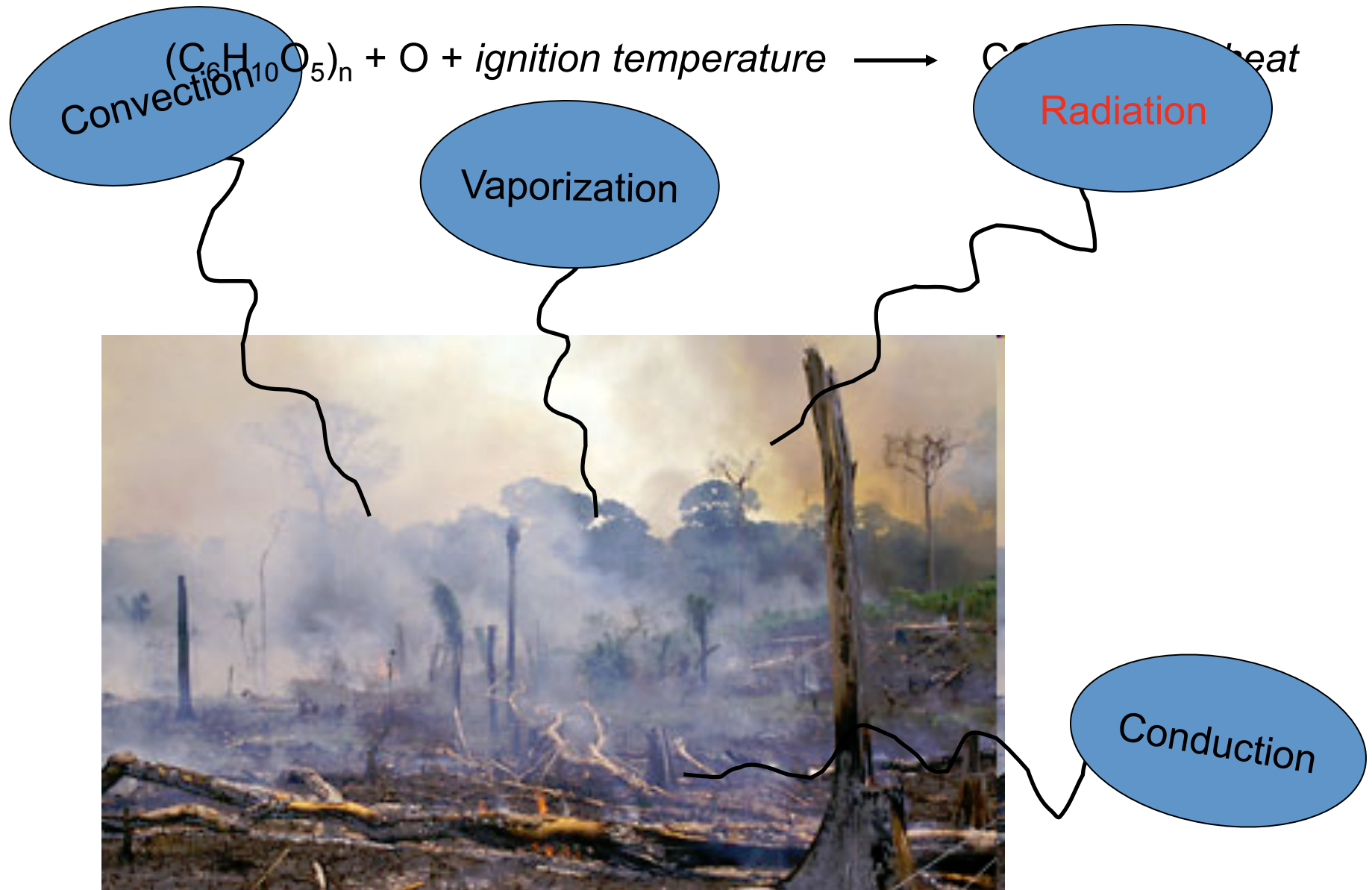


Figure 4. 2008 BC emissions (Gg) from cropland burning in Russia by emission factor source.

An aerial photograph of a fire, likely a wildfire, with a large, dark, irregularly shaped fire area in the center. The surrounding landscape is brown and textured, possibly dry vegetation or soil. Numerous small, red, irregularly shaped bounding boxes are scattered across the image, primarily around the fire area, indicating areas of interest or data points for analysis.

Fire Radiative Energy (FRE) Emission Estimate Approach: Preliminary Results



Fire Radiative Power (FRP)

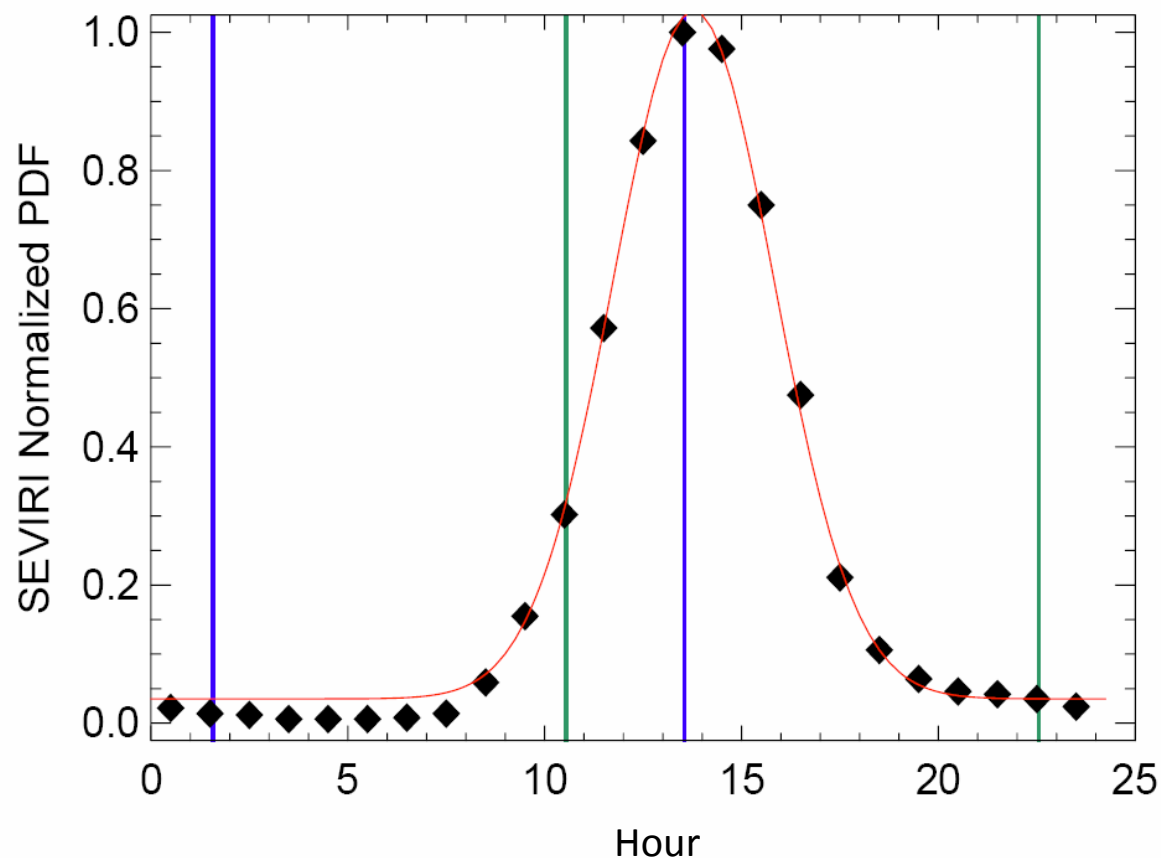
FRP – (MW) rate of fire radiative energy emitted during combustion.

FRE – (MJ) the integral of FRP over time and space

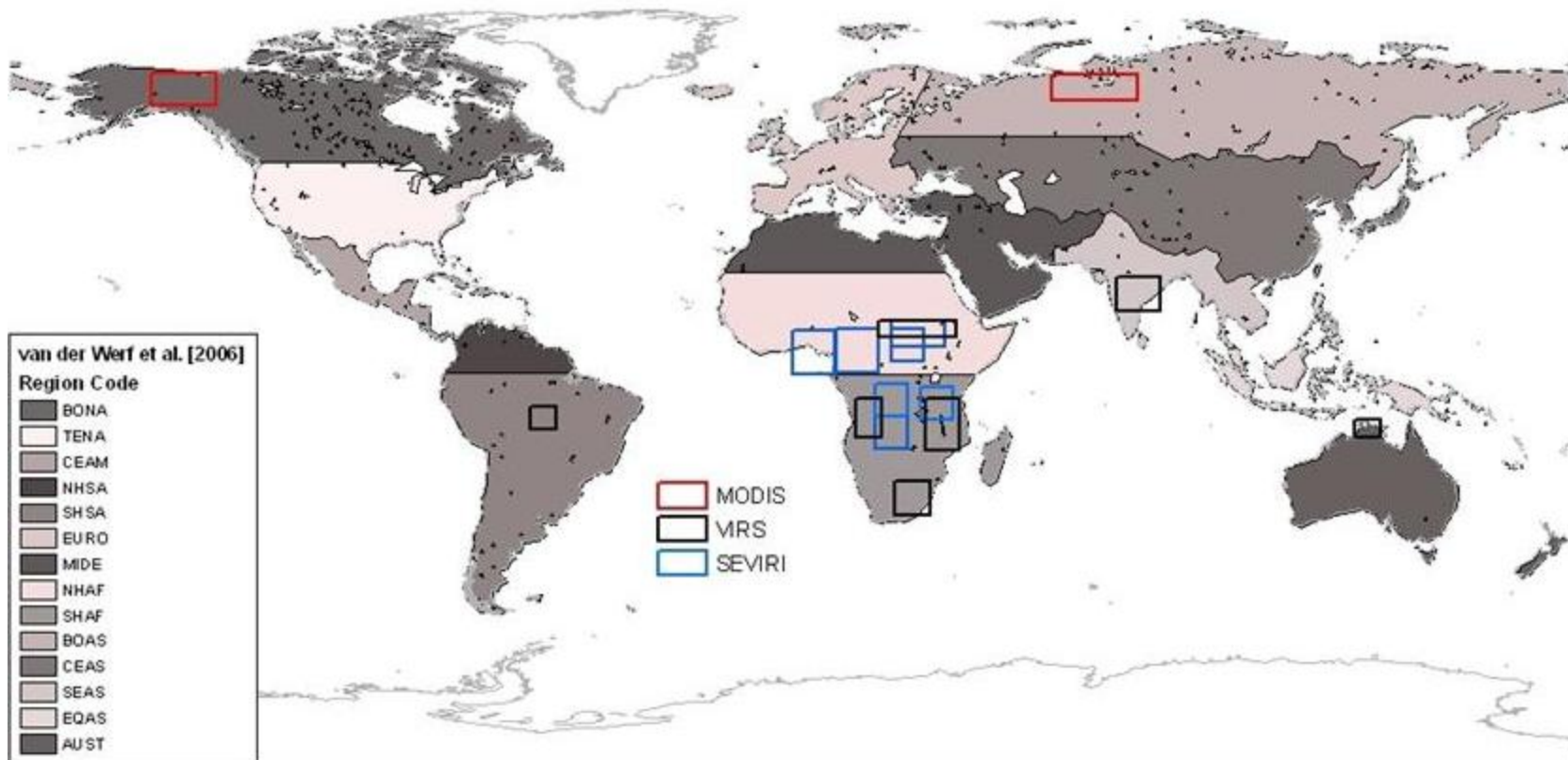
The MODIS sensor estimates the rate of radiative energy emitted from biomass burning, referred to as the fire radiative power (FRP, units in MW), using an empirical relationship relating the difference in the “fire pixel” and “background pixel” 4 μm brightness temperatures [*Kaufman et al.*, 1998].

MODIS

The MODIS sensors, onboard the sun-synchronous polar-orbiting satellites Terra and Aqua, acquire four observations of nearly the entire Earth daily at 1030 and 2230 (Terra) and 0130 and 1330 (Aqua), equatorial local time.

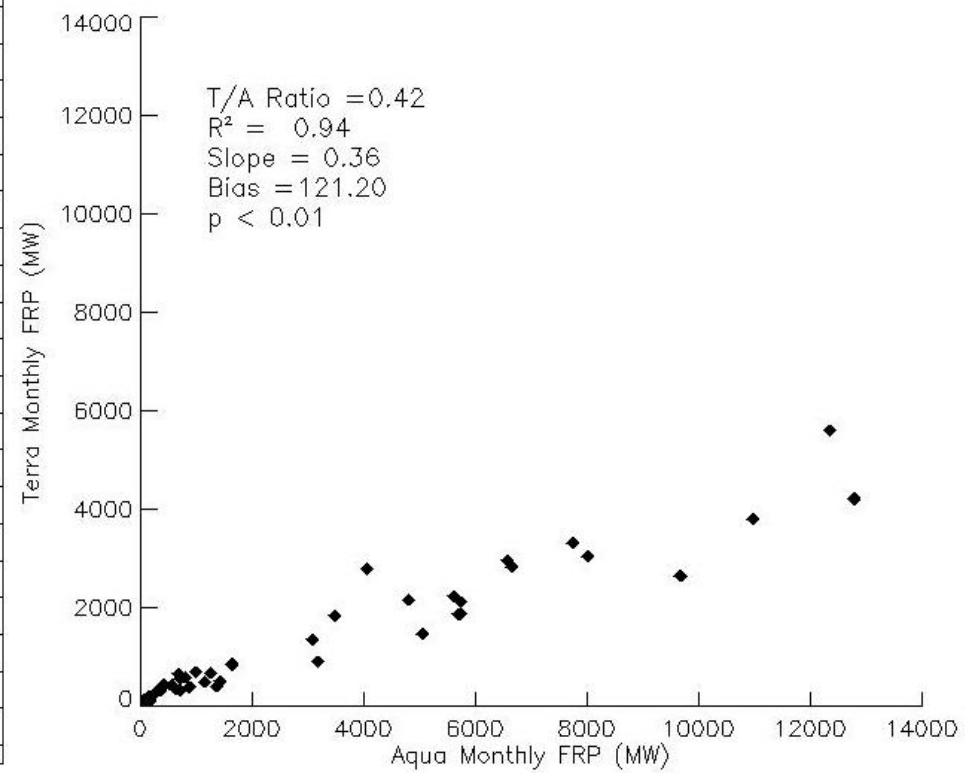
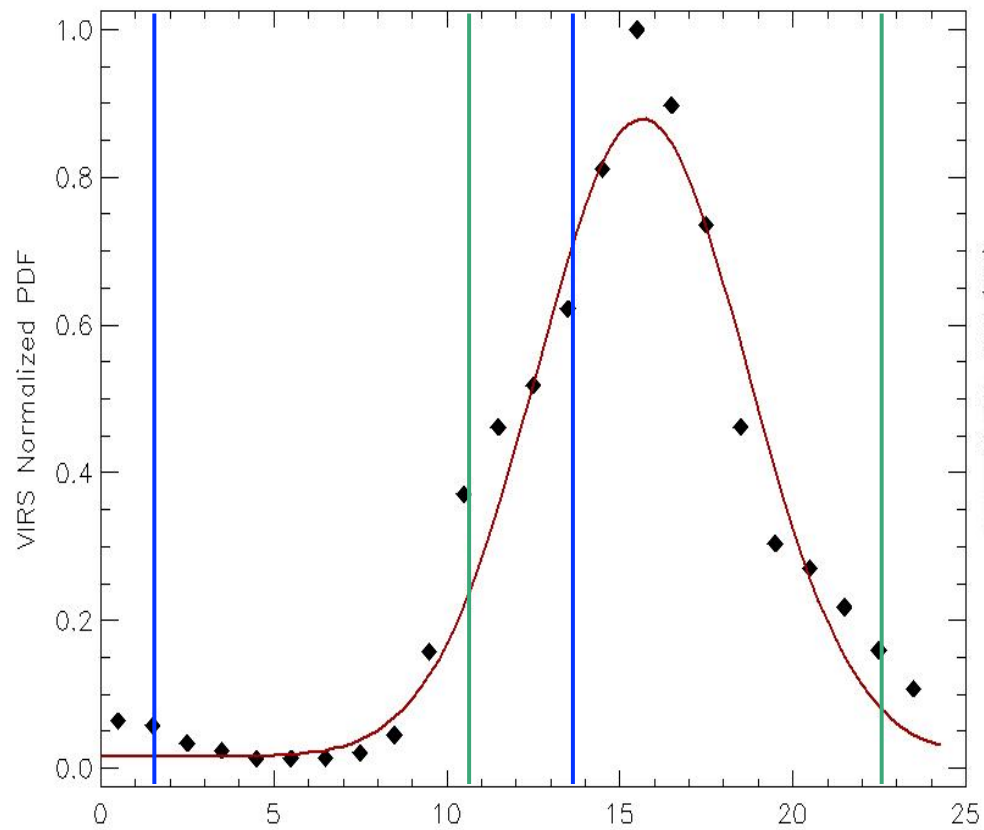


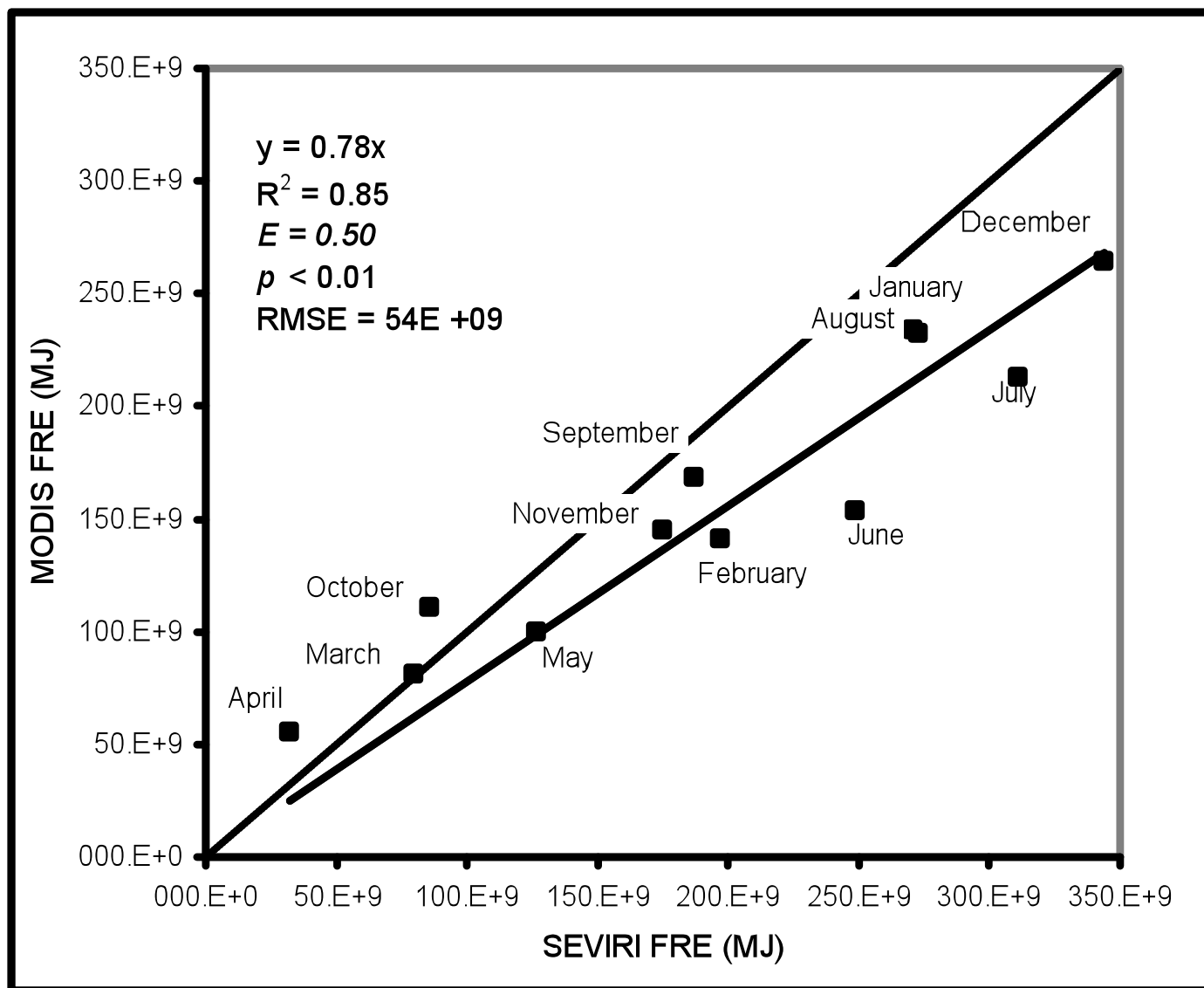
Temporal Trajectories



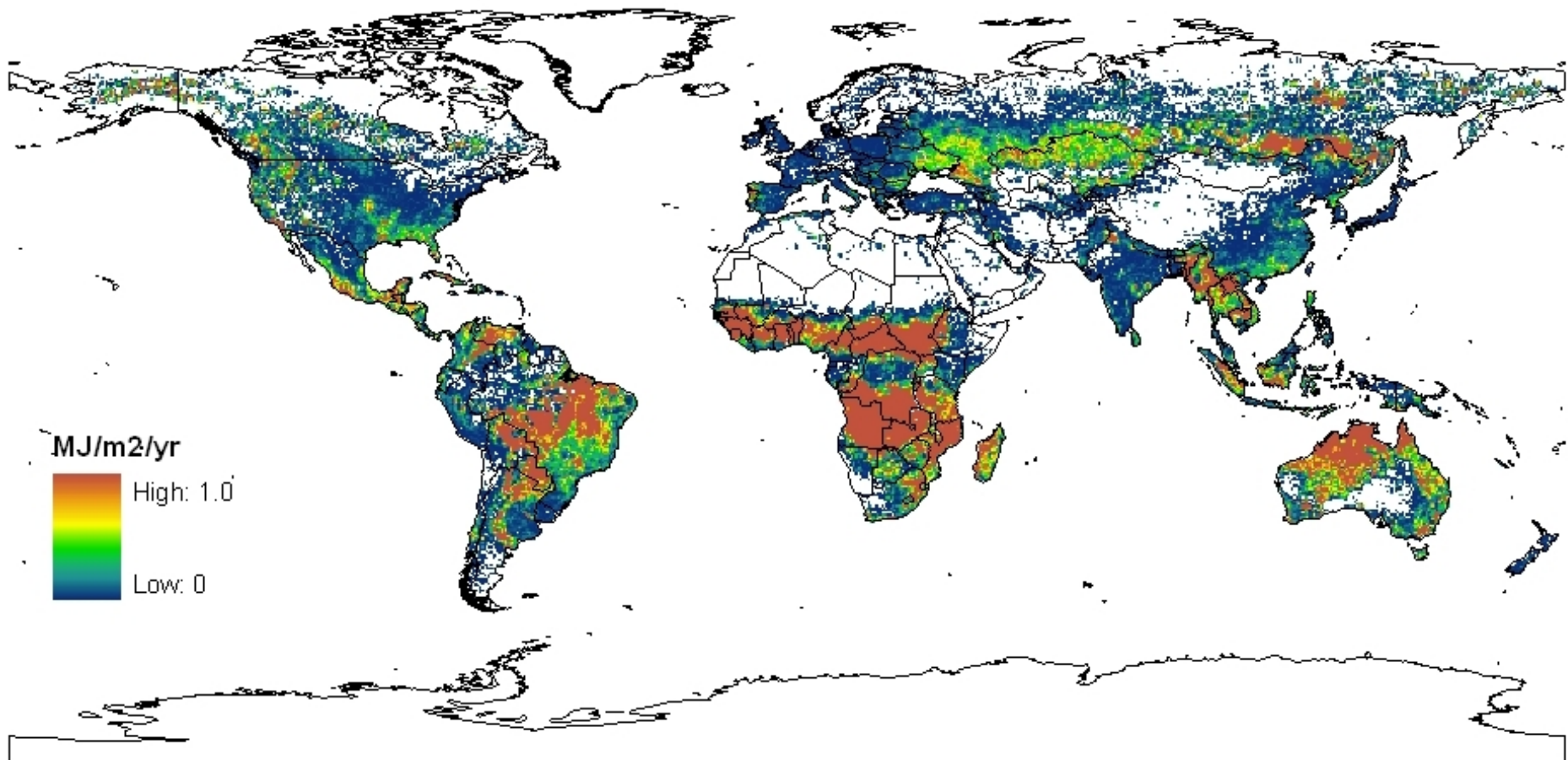
$$FRP(t) = FRP_{peak} \left(b + e^{-\frac{(t-h)^2}{2\sigma^2}} \right)$$

FRE





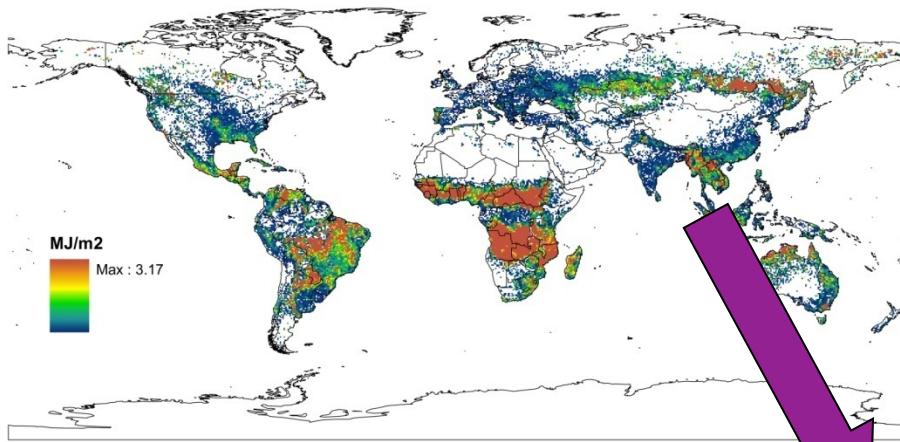
Fire Radiative Energy



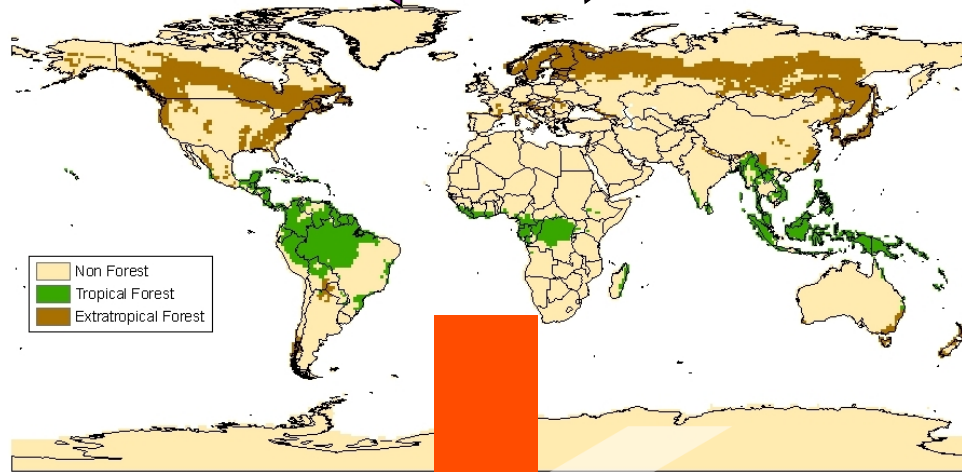
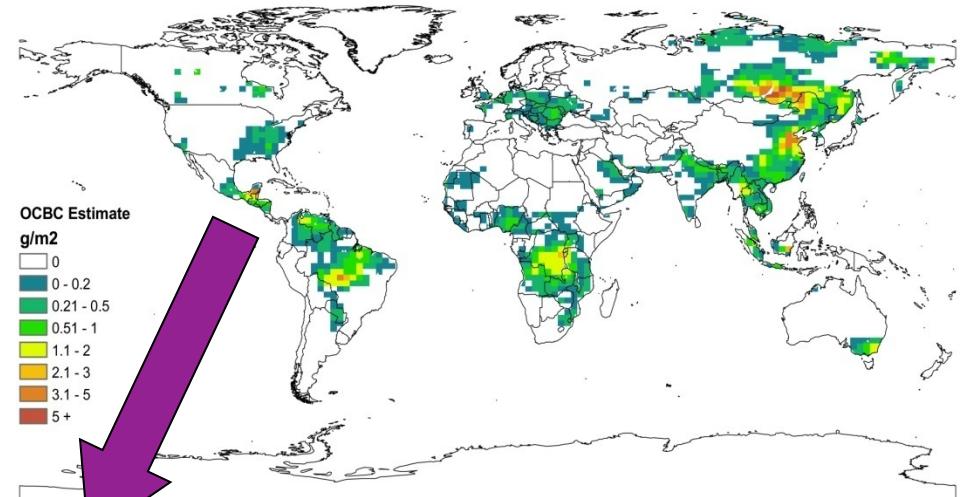
Organic and Black Carbon Aerosols

FRE CMG

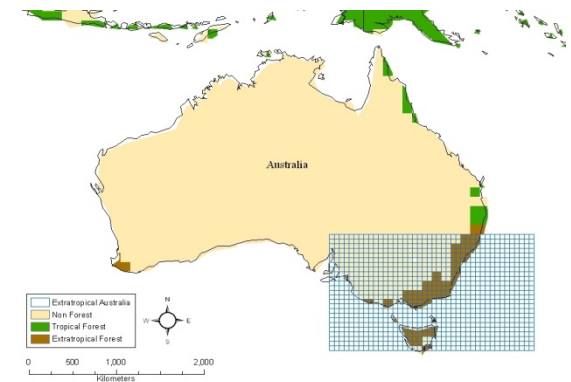
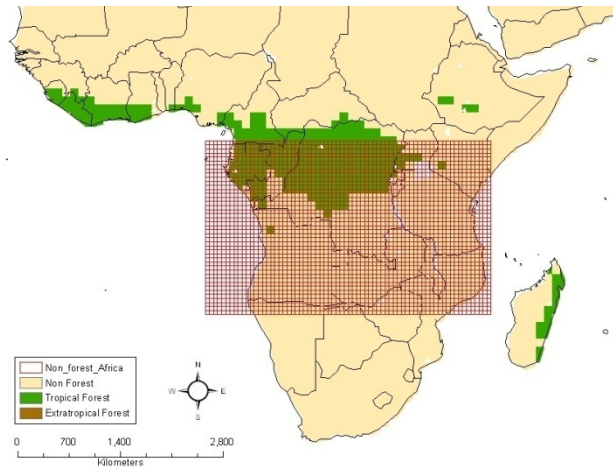
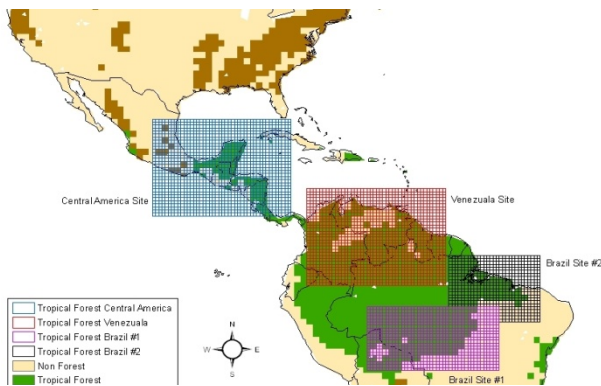
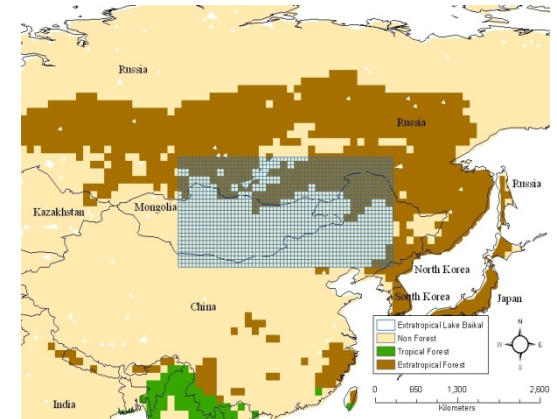
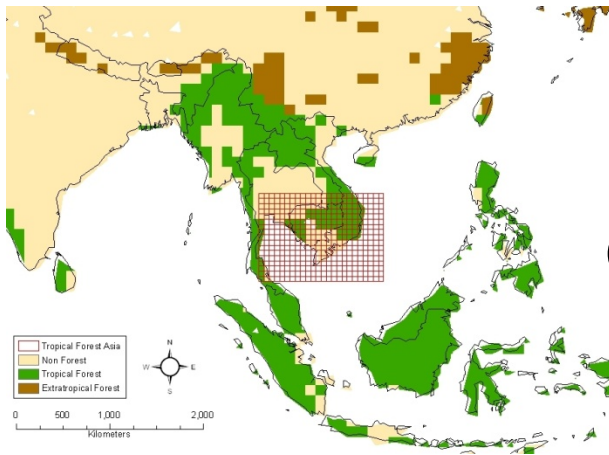
Estimated Total FRE: 2003



OC & BC



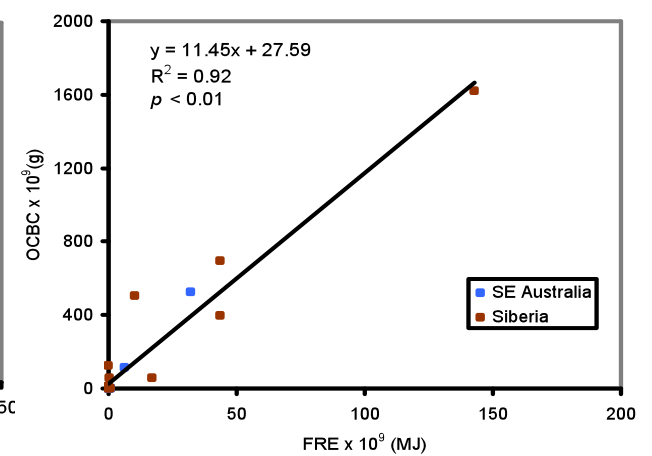
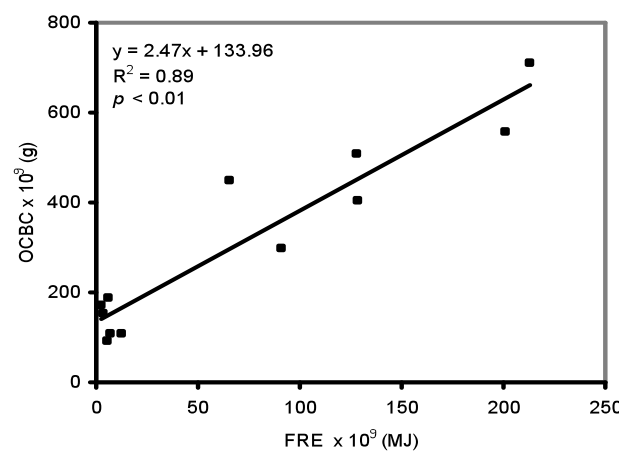
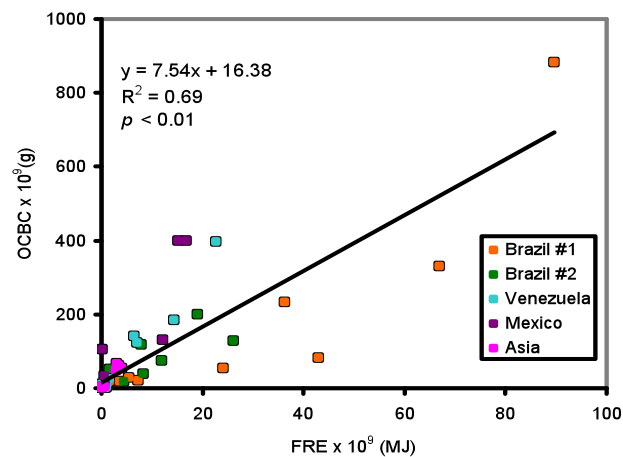
FRE-based emission coefficients



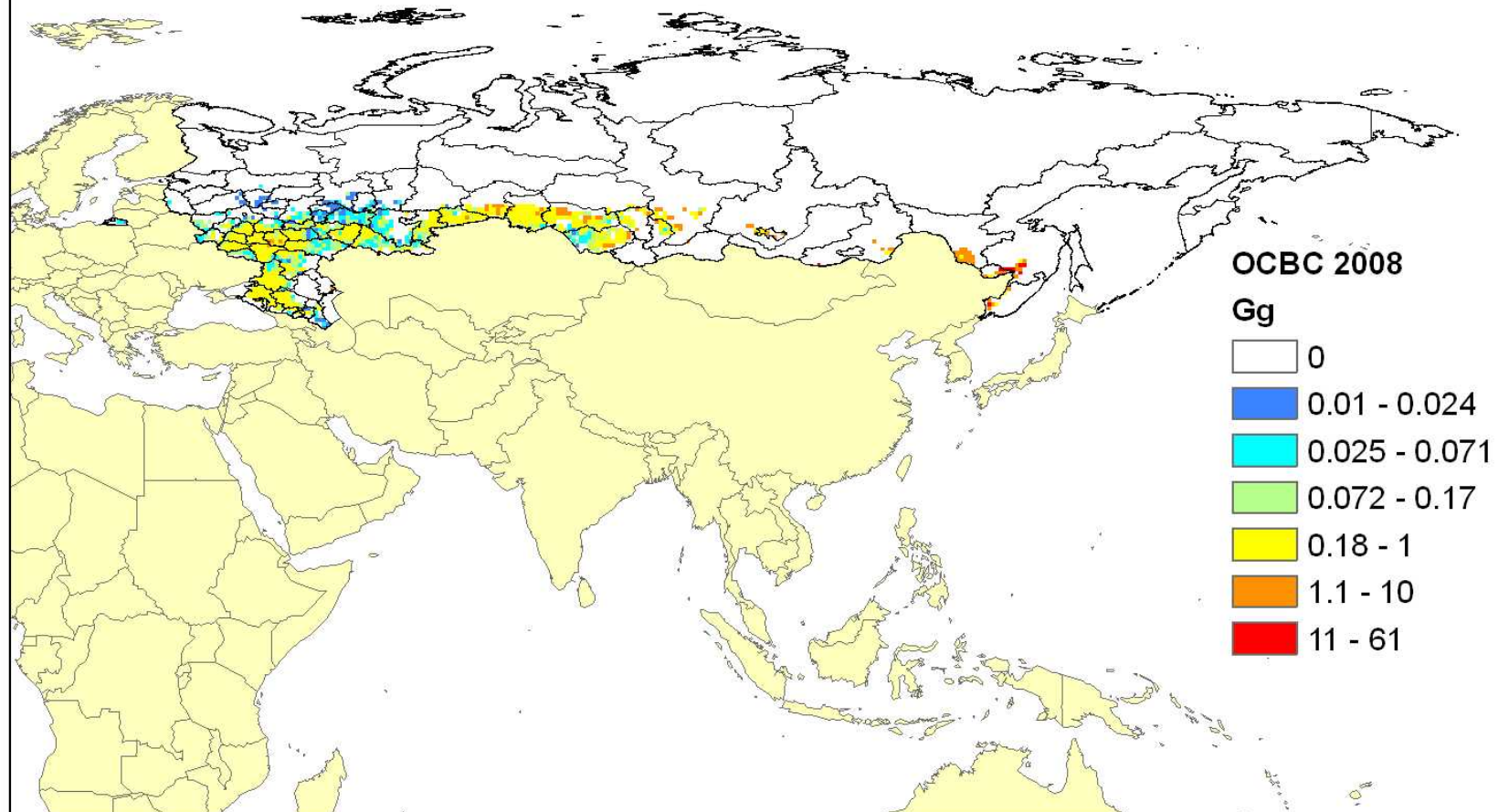
Tropical Forest

Non Forest

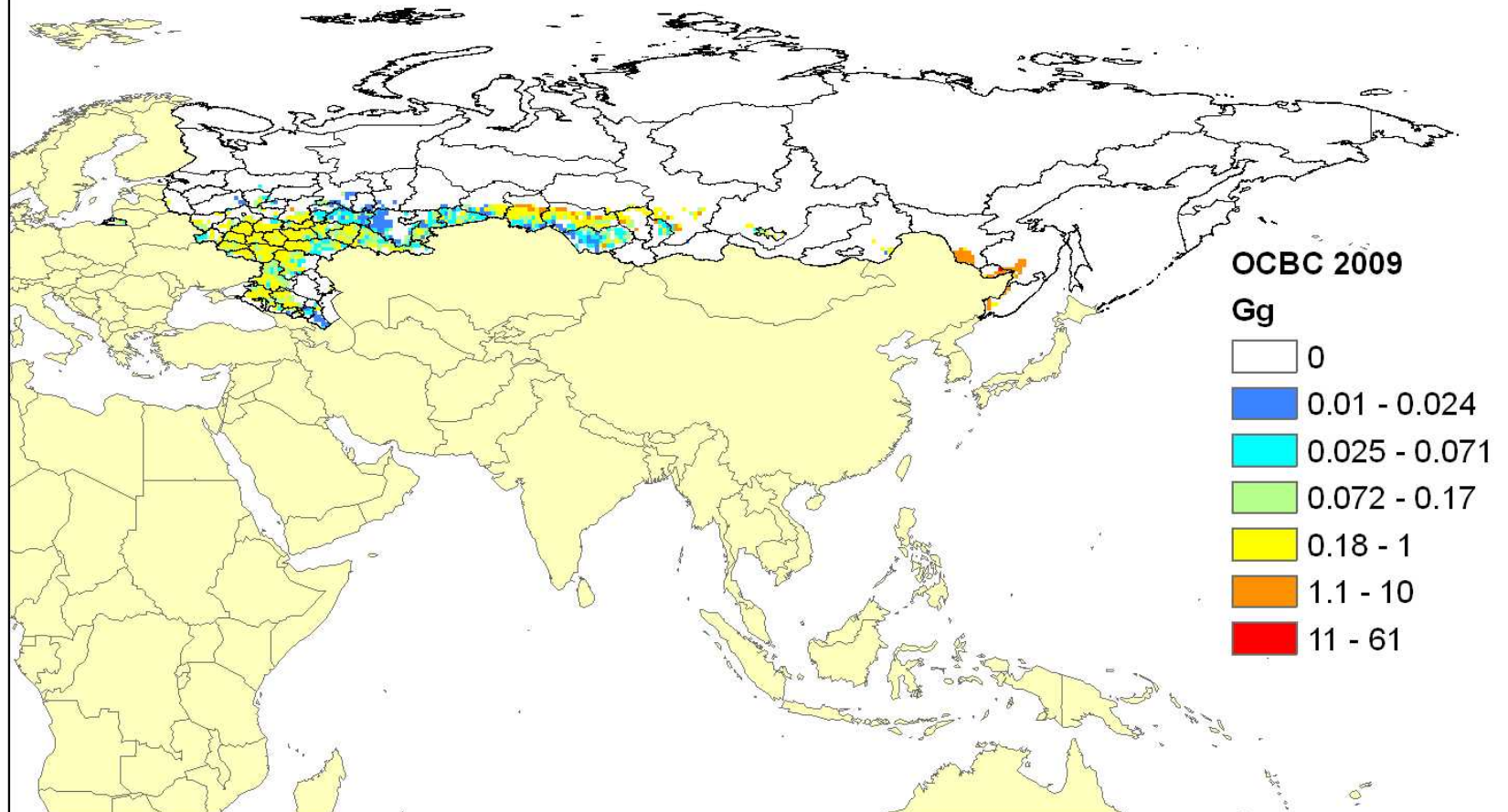
Extratropical Forest



Russian Fire Emissions: Croplands



Russian Fire Emissions: Croplands



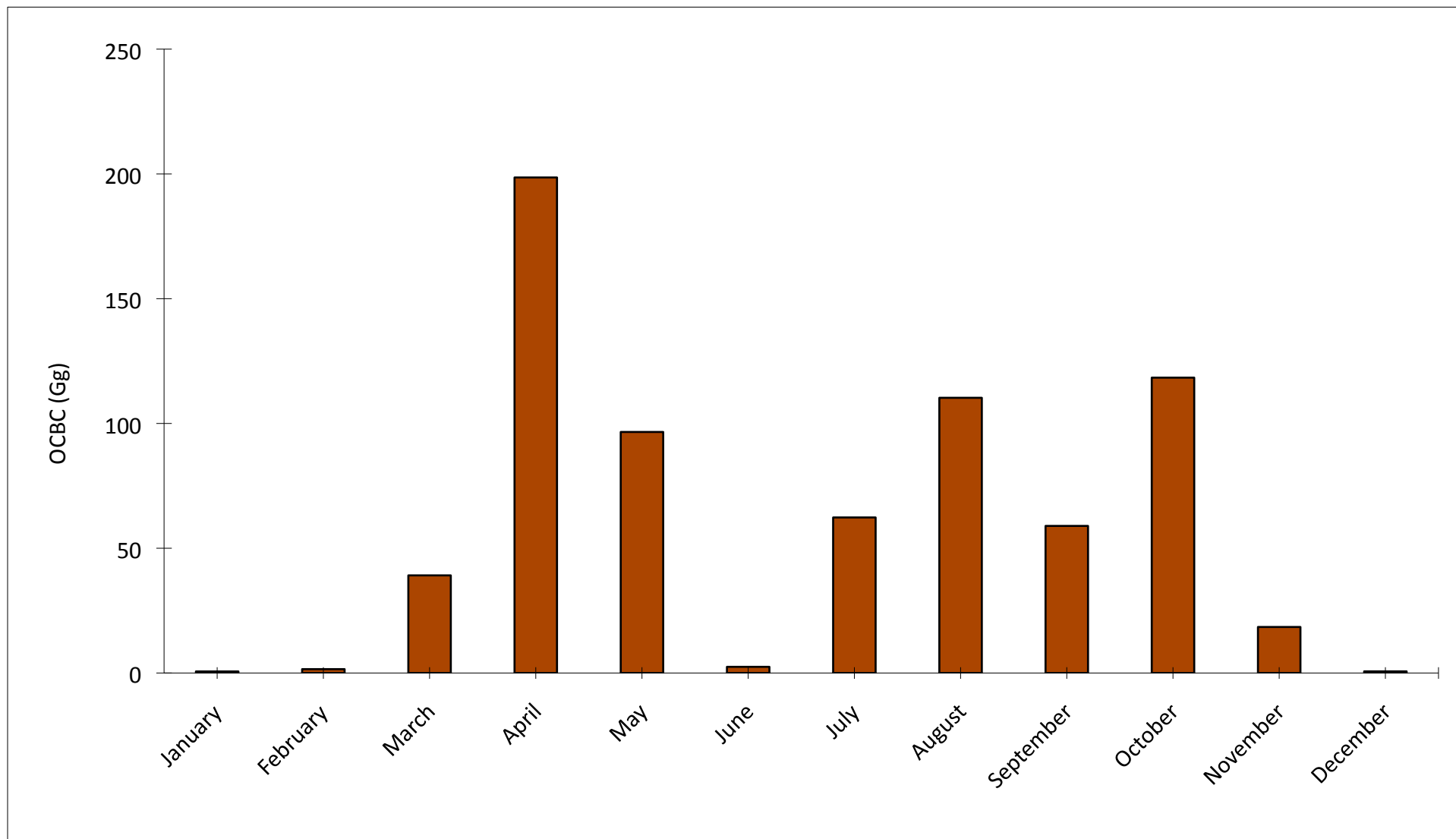


Figure 5. **Average** monthly OCBC emissions from cropland burning in Russia using FRE approach and IGBP cropland classification, 2001 – 2009.

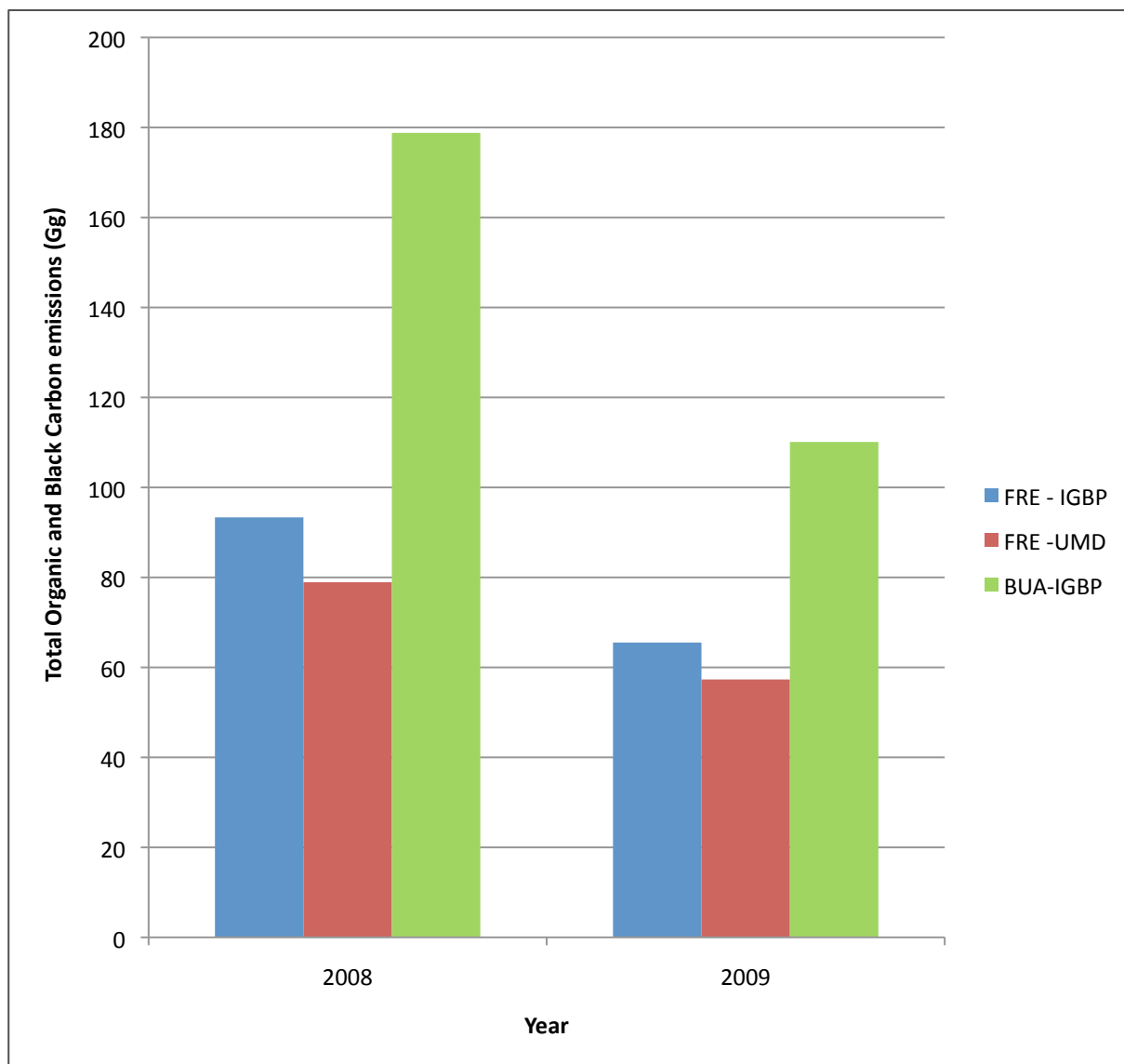


Figure 6. Comparison of OCBC emissions from FRE-IGBP and FRE-UMD cropland classifications to Bottom-Up Approach-IGBP cropland classification, 2008 and 2009.

- UMD cropland classification eliminates the 'cropland-natural vegetation mosaic' class present in the IGBP cropland classification.
- FRE-UMD emissions are 18% and 14% less than the FRE-IGBP estimates for 2008 and 2009, respectively.
- Bottom-Up Approach (BUA) emissions from the IGBP cropland classification are 48% and 56% higher than the FRE-IGBP and FRE-UMD estimates, respectively, for 2008.
- BUA-IGBP emissions are 40% and 48% higher than the FRE-IGBP and FRE-UMD estimates, respectively, for 2009.

A dramatic sky with dark, swirling storm clouds over a green field. The clouds are dark and heavy, with some lighter patches where the sun might be breaking through. The field is a vibrant green, and a line of trees is visible on the horizon.

Questions?